A Comparison of Soil Moisture Regimes from Measured and Modeled Data

H.R. Mount, R.J. Engel, and R.F. Paetzold; Soil Scientists, National Soil Survey Center, USDA-NRCS, Lincoln, Nebraska

Background & Purpose

The Soil Climate Analysis Network consists of 21 climate stations that were installed in the 1990s as part of an NRCS Global Change Initiative. Six of these stations, representing different climate regimes, were selected for this study (Figure 1). The purpose of this study was to compare the moisture regime determined from measured soil moisture data against that predicted by the Newhall Simulation Model (Van Wambeke et al., 1991). Another purpose was to evaluate soil moisture regime definitions to determine if any changes are needed in Soil Taxonomy.

Study Area

The study area consists of the soils at the climate stations in Georgia, Kentucky, Minnesota, North Dakota, Wyoming, and Washington (Figure 2). All of the sites are nearly level and covered with grass vegetation. The soil moisture regimes range from udic to aridic. Additional data for the sites are presented in Table 1.

Methods

Soil moisture measurements were collected hourly from 1997 to 1999 using Vitel Hydroprobe® sensors at the 5-, 10-, 20-, 50-, and 100-cm depths. The output of this sensor is volumetric water content (%). Using NSSC laboratory characterization data from each site, the volumetric water content at 1500-kPa tension was determined for each horizon by multiplying the 1500-kPa water content by the moist (33 kPa) bulk density. The upper and lower boundaries of the soil moisture control sections were then calculated using the water retention difference between 10 or 33 and 1500 kPa (Soil Survey Staff, 1999) (Table 2). Data were then plotted in Microsoft Excel and the number of days when the soil was dry (>1500 kPa tension) for each year was determined (Figure 3). Using Soil Taxonomy, a soil moisture regime was then assigned to each soil (Soil Survey Staff, 1999). Data for 1997 and 1998 were calculated using the Newhall Simulation Model. Measured air temperature and precipitation data collected at or near the sites for each year were used in the Model. The measured available water was also used. The climatic data were not available for 1999.

References

Hurt, G.W., C.V. Noble, and R.W. Drew. 1995. *Soil Survey of Monroe County, Keys Area, Florida*. USDA-NRCS. Washington, D.C.

Mount, H.R. 2000. Soil Temperature Findings for the Camden Farms Cropping System Study. USDA-NRCS, Lincoln, NE.

NRCS Soil Climate Team. 1995. *Distribution of soil climate Stations for the United States.* H.R. Mount, ed. USDA-NRCS. Lincoln, Nebraska. 12 pp.

Soil Survey Staff. 1999. Ag Handbook 436 *Soil Taxonomy: A Basic System of Classification for Making and Interpreting Soil Surveys*. USDA-NRCS. Washington, D.C.

Van Wambeke, A., P. Hastings, and M. Tolomear. 1991. *Newhall Simulation Model – A BASIC program for the IMB PC (DOS 2.0 or later)*. Dept. of Agron. Cornell Univ., Ithaca, NY. 37 pp.

Table 1 – Site Characteristics and Soil Moisture Regimes for the Study Area

State	Latitude (North)	Longitude (West)	Soil Series (Name)	Series Moisture Regime	Series Temperature Regime
GA	33°53.05'	083°25.67'	Cecil	Udic	Thermic
KY	37°06.15'	087°50.45'	Zanesville	Udic	Mesic
MN	45°24.90'	093°56.86'	Hubbard	Udic	Frigid
ND	46°46.62'	100°54.45'	Wilton	Ustic	Frigid
WA	46°26.34'	119°01.22'	Ritzville	Aridic (Xeric)	Mesic
WY	42°03.80'	104°09.10'	Dwyer	Aridic (Ustic)	Mesic

Table 2 – Moisture Control Sections for Soils as defined in Soil Taxonomy

State	Top of the Moisture Control Section (cm)	Bottom of the Moisture Control Section (cm)
GA	32	70
KY	8	24
MN	17	91
ND	9	41
WA	8	22
WY	52	175

Table 3 – Comparison of Days Dry from the Newhall Model vs. Measured Data

State	Newhall DIAL 1997	Newhall DISP 1997	Measured DIAL 1997	Measured DISP 1997	Newhall DIAL 1998	Newhall DISP 1998	Measured DIAL 1998	Measured DISP 1998	Measured DIAL 1999	Measured DISP 1999
GA	0	24	7	253	0	37	132	206	139	198
KY	39	59	0	0	43	56	0	0	23	48
MN	0	25	0	180	29	93	0	208	5	123
ND	167	276	0	125	0	26	16	99	0	68
WA	198	360	87	104	159	234	153	173	159	185
WY	62	82	0	119	213	265	34	104	3	175

DIAL = Dry in all parts. DISP = Dry in some or all parts.

Table 4 – Measured Moisture Regimes

State	Soil Moisture Regime 1997	1998	1999
GA	Aridic Ustic	Aridic Ustic	Aridic Ustic
KY	Udic	Udic	Udic
MN	Typic Ustic	Typic Ustic	Udic Ustic
ND	Typic Ustic	Typic Ustic	Udic
WA	Xeric	Xeric Aridic	Xeric Aridic
WY	Typic Ustic	Typic Ustic	Aridic Ustic

Table 5 – Classification of Soil for the Study Area Using Measured Data

State	Soil Series	Year	Classification (Name)
GA	Cecil	1997	Very-fine, kaolinitic, thermic Aridic Kanhaplustults
		1998	Very-fine, kaolinitic, thermic Aridic Kanhaplustults
		1999	Very-fine, kaolinitic, thermic Aridic Kanhaplustults
KY	Zanesville	1997	Fine-silty, mixed, active, mesic Oxyaquic Fragiudalfs
		1998	Fine-silty, mixed, active, mesic Oxyaquic Fragiudalfs
		1999	Fine-silty, mixed, active, mesic Oxyaquic Fragiudalfs
MN	Hubbard	1997	Sandy, mixed, mesic Entic Haplustolls
		1998	Sandy, mixed, mesic Entic Haplustolls
		1999	Sandy, mixed, mesic Udorthentic Haplustolls
ND	Wilton	1997	Fine-silty, mixed, superactive, frigid Pachic Haplustolls
		1998	Fine-silty, mixed, superactive, frigid Pachic Haplustolls
		1999	Fine-silty, mixed, superactive, frigid Pachic Hapludolls
WA	Ritzville	1997	Coarse-silty, mixed, superactive, mesic Calcic Haploxerolls
		1998	Coarse-silty, mixed, superactive, mesic Calcic Haploxerolls
		1999	Coarse-silty, mixed, superactive, mesic Calcic Haploxerolls
WY	Dwyer	1997	Sandy, mixed, mesic Typic Ustipsamments
		1998	Sandy, mixed, mesic Typic Ustipsamments
		1999	Sandy, mixed, mesic Aridic Ustipsamments

Results

Results of the number of days dry in all and some parts of the moisture control section from the Newhall Simulation Model and measured data are shown for 1997 and 1998 in Table 3. The measured soil moisture data for 1999 are also presented.

The fine-silty soil at Mandan, North Dakota, has an ustic soil moisture regime in 1997 and 1998 and a udic regime in 1999 by measured data. It has an ustic aridic regime in 1997 and a udic regime in 1998 by the Newhall Model.

The sandy soil at Crescent City, Minnesota, has a typic ustic moisture regime in 1997 and 1998 and a udic ustic regime in 1999 by measured data. It has a udic regime in 1997 and a typic ustic regime in 1998 by the Newhall Model.

Figure 1. Location of sites in the study area.

The coarse-silty soil at Lind, Washington, has an aridic soil moisture regime with a distinct xeric soil moisture regime signature (see Figure 3). This soil had a xeric moisture regime in 1997 and a xeric aridic regime in 1998 and 1999 by measured data. The Newhall Model predicts a xeric aridic regime for both 1997 and 1998.

The fine-silty soil at Princeton, Kentucky, has a udic regime in all three years by measured data (see Figure 4). The Newhall Model predicts more periods of dryness than were measured. This soil has a fragipan that perches water during wet periods.

The sandy soil at Torrington, Wyoming, has a typic ustic soil moisture regime in all three years (1997-1999) by measured data. It has a udic regime in 1997 and an aridic regime in 1998 by the Newhall Model.

The very-fine soil at Watkinsville, Georgia, has an aridic ustic moisture regime in all three years by measured data. It has a udic regime by the Newhall Model. Figure 5 is a plot of the moisture reading for 1998 at this site.

Summary of Sites

- Data from this study suggest that the present moisture regime definitions in Soil Taxonomy are adequate for National Cooperative Soil Survey activities in the U.S. Except for the soils with an ustic moisture regime at Crescent City, Minnesota, and Watkinsville, Georgia, the findings of this study are consistent with state and MLRA soil survey correlation decisions.
- Table 4 shows the soil moisture regime and subgroup for each site from 1997 to 1999. The moisture regime and subgroup remained the same each year only for the sites in Georgia and Kentucky. The North Dakota site was typic ustic for two years and udic during 1999. The Minnesota site was typic ustic during 1997 and 1998 and udic ustic during 1999. The Washington site was xeric in 1997 and xeric aridic in 1998 and 1999. The Wyoming site was typic ustic in 1997 and 1998 and aridic ustic in 1999.
- Using laboratory data and measured soil moisture data, the classification of the soil during each year of the study was assigned. These findings are presented in Table 5. The classification of the soils changed in North Dakota, Minnesota, Washington, and Wyoming because of the change in the classification of the soil moisture regime. At the other sites, they remained constant for the period of record.

Figure 2. The climate station at Mandan, North Dakota.

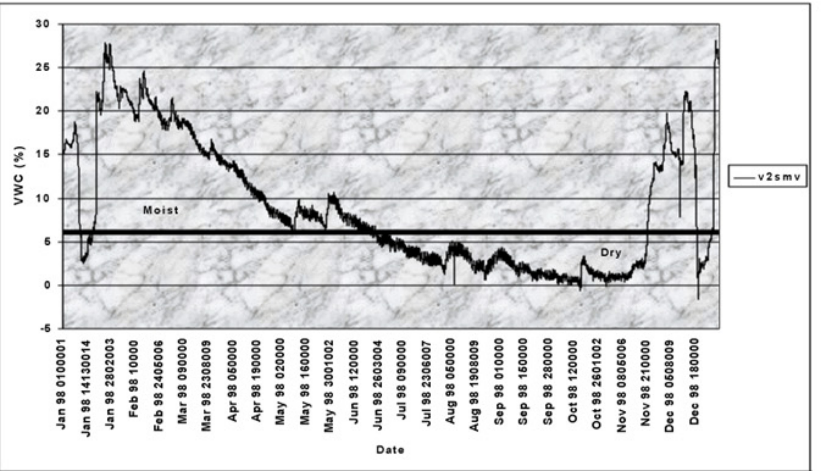

Figure 3. Xeric Aridic soil moisture signature for the 10-cm depth during 1998 at Lind, Washington.

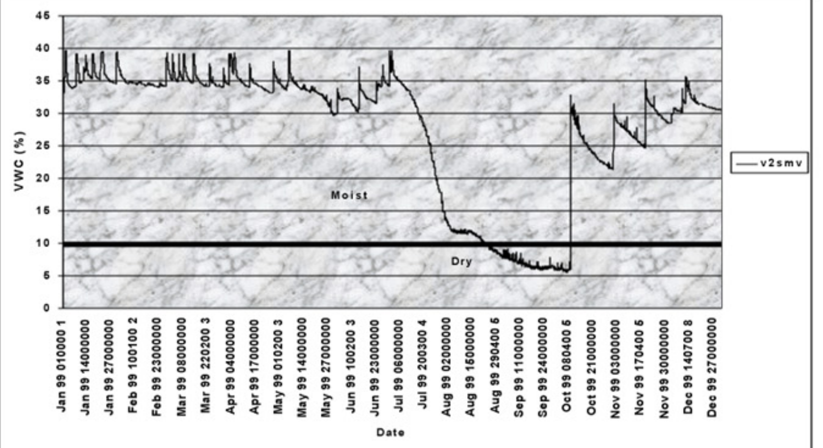

Figure 4. Soil moisture signature at 10 cm during 1999 for the Zanesville soil at Princeton, Kentucky.

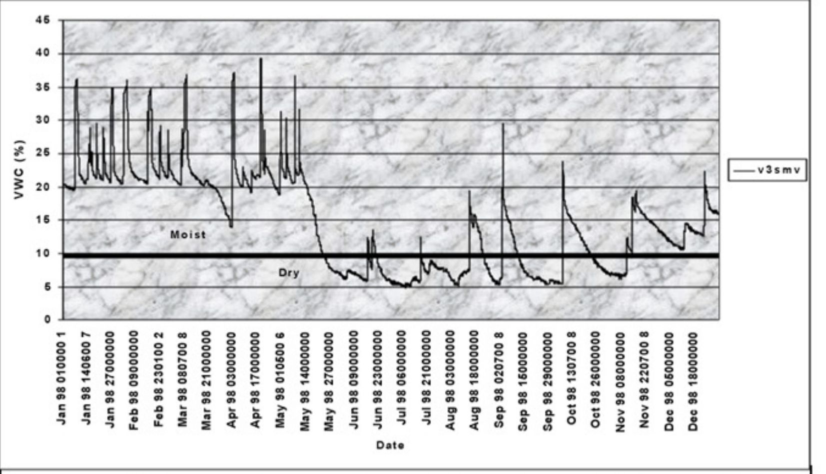

Figure 5. Moisture signature for 1998 showing rapid changes in volumetric water content at the 20-cm soil depth for Watkinsville, Georgia. This depth was dry for a total of 132 days.

Discussion

Soils with a sandy particle-size control section have a lower moisture holding capacity and a thicker, deeper moisture control section than loamy soils (Soil Survey Staff, 1999). Excessively drained, sandy soils warm up sooner and have a warmer annual soil temperature in a similar landscape setting and cropping system than loamy soils (Mount, 2000). Sandy soils in a humid climate are dry for more days during the year than a loamy soil. To date, the only survey area in the U.S. east of the Mississippi River where soils with ustic soil moisture regimes have been correlated is in the Keys of Monroe County, Florida (G.W. Hurt et al., 1995). This study suggests that excessively drained soils with sandy particle-size classes may have an ustic moisture regimes in other parts of the eastern U.S. Excessively drained sandy soils in Mason County, Illinois, and Lake County, Florida, need irrigation to produce commercial crops during summer months. In light of recently measured soil moisture data, the reason now appears clear. Excessively drained sandy soils at these locations may have an ustic moisture regime.

Laboratory data show that soils with kaolinitic mineralogy have a lower moisture holding capacity than comparable soils with smectitic mineralogy. Consequently, soils such as Cecil in Watkinsville, Georgia, have a deeper moisture control section. The soil moisture signature indicates an abrupt increase in volumetric water content with precipitation events and a sharp decline after these events (Figure 5). Due to the strong structure of the Cecil soil, roots are not impeded from locating a zone of higher moisture content (100 cm). It is suggested that crops growing in Cecil soil attain their relatively high productivity by obtaining moisture beneath the defined soil moisture control section. While clayey soils in the Piedmont of the southeast U.S. have not been considered to have an ustic soil moisture regime, measured data from this study suggest that they do. However, data from one station for three years are not enough to make generalizations about the moisture status of the Cecil soil throughout its wide area of extent.

The moisture status of a soil will probably vary with land use for the same soil, i.e., the moisture of a soil will change as land use changes from cropland to pasture to woodland although other soil properties may remain constant. Until more sites are monitored across other climatic zones of the U.S. and data are reviewed, no proposals will be made to alter the current definitions of soil moisture regimes in Soil Taxonomy.

Acknowledgment

Paul Reich, Geographer, World Soil Resources, Washington, D.C., is cited for running the Newhall Simulation Model at each of the sites in this study.